GREGORY CHIONIADES AND PALAEOLOGAN ASTRONOMY

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FOR almost seven centuries following the publication of the commentary on the Handy Tables of Theon by Stephanus of Alexandria[1] little interest was shown in mathematical astronomy in Byzantium. It is true that, in the ninth century, under the leadership of Leo the Mathematician,[2] the text of Ptolemy's Almagest was studied and copied,[3] and that scholars in the eleventh and twelfth centuries had learned something of Arabic science. But it seems improbable that many, save perhaps the astrologers, had the motivation or the training necessary for an attempt to understand more than the most elementary principles of the motions of the celestial spheres; and even the astrologers really needed nothing beyond an ability to manipulate tables.

This neglect continued into the thirteenth century, both at Nicaea and in Constantinople after it had been recovered from the Latins. But the beginnings of a revival of astronomical studies can be traced to the early decades of this century when a few scholars sought to sustain Greek learning under the patronage of John III Vatatzes (1222–1254) and Theodore II Lascaris (1254–1258).

Nicephorus Blemmydes,[4] who taught at the Imperial court from 1238 to 1248 and whose pupils included George Acropolites,[5] reawakened an interest in ancient Greek science which had been virtually dead since the time of Michael Psellos[6] in the eleventh century. His *Epitome physica*[7] is a completely unoriginal book, and its treatment of astronomy (chapters 25–30) is pitifully inadequate. He has very little that is sensible to say about planetary theory; but he does demonstrate that he has read Aristotle, Cleomedes, and Euclid

[1] See H. Usener, *De Stephano Alexandrino* (Bonn, 1880), pp. 33–54, reprinted in his *Kleine Schriften*, 3 (Leipzig-Berlin, 1914), pp. 289–319, and l'Abbé Halma, Πτολεμαίου καί Θέωνος Πρόχειροι Κανόνες, 3 (Paris, 1825), pp. 101–112; see also G. Sarton, *Introduction to the History of Science*, 1 (Baltimore, 1927), pp. 472–473.

[2] See J. L. Heiberg, "Der byzantinische Mathematiker Leon," *Bibliotheca Mathematica*, NF 2 (1887), pp. 33–36; Sarton, 1, pp. 554–555; and E. E. Lipšic, "Vizantijskij učenyj Lev Matematik," *Vizantijskij Vremennik, N.S.*, 2 (1949), pp. 106–149.

[3] Heiberg in his edition of the Almagest (Leipzig, 1898–1903) lists three ninth-century manuscripts (Par. gr. 2389, Vat. gr. 1291, and Vat. gr. 1594), one of the tenth (Marc. gr. 313), one of the twelfth (Vat. gr. 180), two of the thirteenth (Par. gr. 2390 and Vat. gr. 184), and two of the thirteenth or fourteenth (Marc. gr. 311 and Vat. gr. 1038).

[4] See K. Krumbacher, *Geschichte der byzantinischen Literatur*, 2nd ed. (Munich, 1897), pp. 550–554; Sarton, 2 (1931), p. 971; and H.-G. Beck, *Kirche und theologische Literatur im byzantinischen Reich* (Munich, 1959), pp. 671–673. For an example of his astronomical wisdom, see J. B. Bury, "An Unpublished Poem of Nicephorus Blemmydes," BZ, 10 (1901), pp. 418–424 and P. N. P(apageorgiu), "Zu Nikephoros Blemmydes, B. Z. X 419 (Bury)," *ibid.*, p. 545.

[5] See Krumbacher pp. 286–288; A. Heisenberg, *Georgii Acropolitae opera*, 2 (Leipzig, 1903), pp. III–XIII; Sarton, 2, pp. 1113–1114; and Beck, pp. 674–675.

[6] See C. Zervos, *Un philosophe néoplatonicien du XI^e siècle, Michel Psellos* (Paris, 1920). On Byzantine education in general, see F. Fuchs, *Die höheren Schulen von Konstantinopel im Mittelalter*, *Byzantinisches Archiv*, 8 (Leipzig-Berlin, 1926); for its condition under Psellos, see L. Bréhier, "L'enseignement supérieur à Constantinople dans la dernière moitié du XIe siècle," *Revue internationale de l'enseignement*, 38 (1899), pp. 97–112. Aristotle, of course, continued to be taught until the fall of the capital in 1204.

[7] Edited in PG, 142, cols. 1005–1302. What is printed as the last chapter (cols. 1303–1320) is, in fact, Nicephorus' commentary on the eighth Psalm; it is different from what is given in col. 1357 ff., which seems to be by Euthymius Zigabenus.

with some comprehension, and he observed at least one lunar eclipse, that of 18 May 1258.[8]

An account[9] of an observation of a solar eclipse by his pupil George Acropolites in the company of the Imperial court on 3 June 1239 reveals the intellectual atmosphere in which Nicephorus was working. The Empress Irene asked Acropolites, then only twenty-one years old, what had caused this phenomenon. He, though he had just begun his studies under Blemmydes, was able to reply correctly that the Moon was interposed between the Earth and the Sun. The court physician, Nicolaus, scoffed at this ridiculous response, and the Empress, trusting her doctor, called Acropolites a fool. She quickly regretted her use of this derogatory term, not because she realized the correctness of Acropolites' explanation, but because she considered it improper to insult one engaged in philosophical studies. Two years later the Empress died; the philosopher seriously suggests that the eclipse was a portent of that unfortunate event, as was also the appearance of a bearded comet. It was Acropolites who, after the capture of Constantinople by Michael VIII Palaeologus in 1261, restored mathematics to the capital; he taught Euclid and Nicomachus to George (later Gregory) of Cyprus and others.[10]

Among his pupils was, apparently, George Pachymeres,[11] a man who progressed much further in astronomical studies than had his teacher. Pachymeres' knowledge of this subject is, naturally, set forth in the fourth book of his Quadrivium.[12] To a large extent this consists of elaborate instructions for the multiplication of sexagesimal numbers, a procedure he regarded as incredibly difficult, a discussion of the risings, settings, and culminations of various constellations, and a number of the fundamental doctrines of astrology, many of which are also found in the *Epitome physica* of his mentor's mentor. He is capable of such improbable statements as: "They say that a yearly revolution of the Sun takes place in 365 degrees (μοίραις for ἡμέραις), 14 minutes, and 48 seconds"; but his planetary theory is far more complete than that of his predecessor, and he himself is far from being confused about everything.

George of Cyprus' friend John Pediasimus[13] continued Blemmydes' study of Cleomedes' Κυκλικὴ θεωρία μετεώρων, on which he wrote a commentary; and

[8] 27, 15 (col. 1265).

[9] George Acropolites, Χρονικὴ συγγραφή, 39 (pp. 67–68, Bonn; 1, pp. 62–64, Heisenberg).

[10] See George of Cyprus' autobiography in W. Lameere, *La tradition manuscrite de la correspondance de Grégoire de Chypre, Études de philologie, d'archéologie et d'histoire anciennes publiées par l'Institut Historique Belge de Rome*, 2 (Brussels-Rome, 1937), p. 185; on George of Cyprus, see Krumbacher pp. 476–478 and Beck pp. 685–686.

[11] See Krumbacher, pp. 288–291; Sarton, 2, pp. 972–973; and Beck, p. 679.

[12] Edited by P. Tannery and E. Stéphanou, Studi e Testi, 94 (Vatican City, 1940). The quotation is from 4, 7 (p. 364).

[13] See Krumbacher, pp. 556–558; Sarton, 3 (1947), pp. 682–683; V. Laurent in *Échos d'orient*, 31 (1932), pp. 327–331; and Beck, pp. 710–711. For his harmonic interpretation of seven- and nine-month births, see V. de Falco, "L'aritmologia pitagorica nei Commenti ad Esiodo," *Rivista indo-greco-italica*, 7, 3/4 (1923), pp. 25–54 and *In Ioannis Pediasimi libellum de partu septemmestri ac novemmestri nondum editum* (Naples, 1923); F. Cumont, "L'opuscule περὶ ἑπταμήνων καὶ ἐννεαμήνων," *Revue belge de philologie*, 2 (1923), pp. 5–21; and J. L. Heiberg in BZ, 25 (1925), pp. 145–146; cf. also Psellos' tract on the same subject edited by S. Weinstock in *Catalogus codicum astrologorum Graecorum*, 9, 1 (Brussels, 1951), pp. 101–103.

other mathematicians of this period were Maximus Planudes,[14] who composed one of the first treatises on Indian numerals in Byzantium[15] and an exegesis of the first two books of Diophantus,[16] and his pupil Manuel Moschopulus, who wrote the first Western treatise on the construction of magic squares.[17] But a scholar more directly interested in the study of mathematical astronomy was Planudes' friend Manuel Bryennius,[18] whose only surviving work is on harmonics, but who is praised by Theodore Metochites[19] as his initiator into the secrets of the heavens in 1314.

Metochites, besides being the most powerful courtier in the empire of Andronicus II, was one of the most intelligent men in Byzantium. With some assistance from Bryennius, but mainly through his own efforts, he succeeded in mastering the Μεγάλη σύνταξις, a feat of which he was justifiably proud and which astounded his contemporaries.[20] His success had two immediate results: the publication of several treatises on Ptolemaic astronomy, of which the most impressive is the Στοιχείωσις and commentary on the Almagest, and the instruction of his brilliant pupil Nicephorus Gregoras.[21] Thus he raised the level of sophistication in Byzantine astronomy to a height it had not attained for centuries.

Gregoras continued Metochites' method of simply trying to understand and explicate the classical texts in his works on eclipses and the astrolabe[22]—subjects in the exposition of which, as in almost everything, he was opposed by

[14] See Krumbacher, pp. 543–546; Sarton, 2, pp. 973–974; C. Wendel, "Planudea," *BZ*, 40 (1940), pp. 406–445; and Beck, pp. 686–687.

[15] It would seem that Indian numerals were known in Byzantium by the twelfth century (see P. Tannery, "Les chiffres arabes dans les manuscrits grecs," *Revue archéologique*, 3rd Ser., 7 [1886], pp. 355–360 reprinted in his *Mémoires scientifiques*, 4 [Toulouse–Paris, 1920], pp. 199–205). But, as there is no evidence that the scholium of the monk Neophytus (P. Tannery, "Le scholie du moine Néophytos sur les chiffres hindous," *Revue archéologique*, 3rd Ser., 5 [1885], pp. 99–102 reprinted in *Mém. Sc.*, 4, pp. 20–26) was written before Planudes' Ψηφοφορία κατ' Ἴνδους (edited by C. I. Gerhardt, *Das Rechenbuch des Maximus Planudes* [Halle, 1865]), the latter must be accepted as the earliest text on the subject to survive in Greek.

[16] Edited by P. Tannery in *Diophanti Alexandrini opera omnia*, 2 (Leipzig, 1895), pp. 125–255.

[17] See Krumbacher, pp. 546–548; P. Tannery, "Le traité de Manuel Moschopoulos sur les carrés magiques," *Annuaire de l'Association pour l'Encouragement des Études Grecques en France*, 20 (1886), pp. 88–118 reprinted in *Mém. sc.*, 4, pp. 27–60; and Sarton, 3, pp. 679–681. The most recent treatment of the history of magic squares is that of S. Cammann, "The Evolution of Magic Squares in China," *Journal of the American Oriental Society*, 80 (1960), pp. 116–124.

[18] See Krumbacher, p. 599 and Sarton, 3, pp. 745–746.

[19] See K. N. Sathas, Μεσαιωνικὴ Βιβλιοθήκη, 1 (Venice, 1872), pp. ι'–ρλη'; Krumbacher, pp. 550–554; R. Guilland, "Les poésies inédites de Théodore Métochite," *Byzantion*, 3 (1926), pp. 265–302 reprinted in his *Études byzantines* (Paris, 1959), pp. 177–205; Sarton, 3, pp. 684–688; I. Ševčenko, "Observations sur les recueils des *discours* et des *poèmes* de Th. Métochite et sur la bibliothèque de Chora à Constantinople," *Scriptorium*, 5 (1951), pp. 279–288; H. Hunger, "Theodoros Metochites als Vorläufer des Humanismus in Byzanz," BZ, 45 (1952), pp. 4–19; H.-G. Beck, *Theodoros Metochites* (Munich, 1952); R. J. Loenertz, "Théodore Métochite et son père," *Archivum Fratrum Praedicatorum*, 23 (1953), pp. 184–194; J. Verpeaux, "Le cursus honorum de Théodore Métochite," *Rev. ét. byz.*, 18, (1960), pp. 195–198; and I. Ševčenko, *Études sur la polémique entre Théodore Métochite et Nicéphore Choumnos*, Corpus Bruxellense Historiae Byzantinae, Subsidia, 3 (Brussells, 1962).

[20] Sathas p. κ', note 3.

[21] Guilland, *Ét. byz.*, pp. 180–186. On Gregoras, see R. Guilland, *Essai sur Nicéphore Grégoras. L'homme et l'oeuvre* (Paris, 1926), and *Correspondance de Nicéphore Grégoras* (Paris, 1927); Sarton, 3, pp. 949–953; and Beck, pp. 719–721.

[22] The two treatises on the astrolabe are edited by A. Delatte, *Anecdota Atheniensia et alia*, 2 (Paris, 1939), pp. 195–235.

Barlaam of Calabria.[23] Only in regard to the calendar did Gregoras claim to have achieved a better result than had his ancient predecessors. Ptolemy, following Hipparchus, had found that the length of a tropical year was 6,5; 14,48 days; Gregoras claims[24] that he himself, by observation, had discovered that it is not quite so long. Isaac Argyrus,[25] in recording this discovery, states that the correction required is obtained by subtracting $\frac{1}{200}$ of a day from the Ptolemaic figure, or about $\frac{1}{100}$ of a day from 365 $\frac{1}{4}$ days. This amounts to adding 0;0,18^{0} per year to the Ptolemaic value of precession, 0;0,36^{0}, a procedure which yields the result 0;0,54^{0} per year. As Isaac remarks, the "Persians" had already arrived at this conclusion. It is the well-known parameter of 1^{0} of precession every 66 years which is ascribed to οἱ νεώτεροι by Simeon Seth in the eleventh century.[26] The same parameter is found in a scholium to Pappus' Prolegomena to the Almagest discovered by Tannery;[27] as this scholium refers to ephemerides which began with 1 March 1032 and attributes the parameter in question to οἱ νεώτεροι, its author may well be Simeon. The scholium correctly refers to the observation of the autumnal equinox by Yaḥyâ ibn Abî Manṣûr under the Caliph al-Ma'mûn on 19 September 830, but does not realize that the value of precession arrived at can actually be traced back to Lâṭadeva's version of the Sûryasiddhânta (A.D. 505) and the lost work of Maṇittha (Μανέθων?).[28]

Simeon Seth also refers to a precession of 0;0,54^{0} per year in an unpublished text in a fourteenth-century manuscript, Vat. gr. 1056, which is a copy of a twelfth-century codex.[29] This text occurs among a collection of five star-

[23] See Krumbacher, pp. 102 and 625; Sarton, 3, p. 583; and Beck, pp. 717–719.

[24] Ῥωμαϊκὴ ἱστορία, 8, 13 (1, pp. 364–373, Bonn).

[25] His work on the computus, written in 1373, is edited by D. Petavius, *Uranologion* (Paris, 1630), pp. 359–383; the passage referred to is on page 381 (cf. also p. 382). It is reprinted in PG, 19, cols. 1279–1316. On Isaac, see G. Mercati, *Notizie di Procoro e Demetrio Cidone, Manuele Caleca e Teodoro Meliteniota, ed altri appunti per la storia della teologia e della letteratura bizantina del secolo XIV*, Studi e Testi, 56 (Vatican City, 1931), pp. 233–236 and *passim*; Sarton, 3, pp. 1511–1512; and Beck, pp. 729–730.

[26] In Περὶ χρείας τῶν οὐρανίων σωμάτων, 70, in Delatte, p. 124. For Simeon, see Krumbacher, pp. 615 and 896 and Sarton, 1, p. 771; for a peculiarity in his astronomical terminology, see M. V. Anastos, "Ὑπόγειος, a Byzantine term for perigee, and some Byzantine views of the date of perigee and apogee," *Orientalia Christiana Periodica* 13 (*Miscellania Guillaume de Jerphanion*) (1947), pp. 385–403.

[27] P. Tannery, "Les éphémérides chez les byzantins," *Bulletin des sciences mathématiques*, 2nd Ser., 30 (1906), pp. 59–63 reprinted in *Mém. sc.*, 4, pp. 289–293. The whole scholium has now been edited by J. Mogenet "Une scolie inédite du Vat. gr. 1594 sur les rapports entre l'astronomie arabe et Byzance," *Osiris*, 14 (1962), pp. 198–221; the passage referred to is on p. 209.

[28] The account by T.-H. Martin in his *Mémoire sur cette question*: *La précession des équinoxes a-t-elle été connue des égyptiens ou de quelque autre peuple avant Hipparque*? (Paris, 1869), pp. 179–188, is based entirely on H. T. Colebrooke, "On the Notion of the Hindu Astronomers concerning the Precession of the Equinoxes and Motions of the Planets," *Asiatic Researches*, 12 (1818), pp. 211–252, reprinted in his *Miscellaneous Essays*, 2 (London, 1837), pp. 374–416. The account given by P. Duhem in his *Le système du monde*, 2 (Paris, 1914), pp. 212–214 and 223–226, is a rather confused version of Martin. I have found in a manuscript (3166 of the Oriental Research Institute, Mysore) of an early ninth-century commentary by Govindasvâmin on the Uttarakhaṇḍa of the Bṛhatpârâśarahorâśâstra a passage which considerably clarifies the Indian tradition and raises the possibility that the Indian theories of precession and trepidation are derived from a Greek source.

[29] It gives horoscopes for the coronations of Alexius I Comnenus in 1081 and of Manuel I Comnenus in 1143. On folio 6^{v} is a horoscopic diagram beneath which is written: Μηνὶ Μαρτίῳ λα' ἡμέρᾳ δ' ἰνδικτιῶνος ς' ἔτους ,ςχνα' γέγονεν ἡ ἀναγόρευσις τῆς βασιλείας τοῦ κραταιοῦ καὶ εὐσεβοῦς ἡμῶν βασιλέως τοῦ Πορφυρογεννήτου κυροῦ Μανουῆλ τοῦ Κομνηνοῦ εἰς Μάμισταν. ἡ δὲ τελευτὴ τοῦ τρισμακαρίστου ἀοιδίμου βασιλέως καὶ πατρὸς αὐτοῦ κατὰ τὸν η' τοῦ Ἀπριλλίου ἡμέρᾳ ε' τῆς αὐτῆς ἰνδικτιῶνος. At the bottom of the page, in a different hand, is written: Μηνὶ Σεπτεμβρίῳ κδ' ἡμέρᾳ δ' ἰνδικτιῶνος δ' ἔτους ,ςχπη' γέγονεν ἡ τελευτὴ τοῦ

catalogues (fols. 30ᵛ–33) derived from the Zîj al-Ḥâkimî,[30] Kûshyâr bin Labbân,[31] the Egyptians,[32] and Abû Ma'shar,[33] as quoted in the Kitâb al-Mughnî of Ibn Hibintâ.[34] The catalogues are dated respectively in 1156, 1161, probably 1142, 1161, and 1148; the longitudes of the stars are fairly consistently computed by allowing a precession of 1^0 for every 66 years from the time of Ptolemy. Thus it is clear that Gregoras' observations, if he really made any, merely confirmed a parameter which had been known in Byzantium for at least two and a half centuries.

The final figures in this conservative tradition of astronomy are Nicolaus

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τρισμακαρίστου καὶ ἀοιδίμου βασιλέως ἡμῶν κυροῦ Μανουῆλ τοῦ Κομνηνοῦ τῷ τῶν μοναχῶν μετασχηματισθέντος σχήματι καὶ [μετὰ] μετονομασθέντος. ἐν τῷ μέσῳ δὲ τοῦ λζ' ἔτους τῆς βασιλείας αὐτοῦ γέγονεν ἡ τούτου τελευτή. I list below the longitudes of the planets as given in the horoscope and those computed for 31 March 1143 at *ca.* 10 A.M.:

	Horoscope	*Computation*
Saturn	Aries 6;0	Aries 3
Jupiter	Aquarius 9;15	Aquarius 8
Mars	Leo 9;36	Leo 5
Sun	Aries 16;52	Aries 16
Venus	Pisces 22;28	Pisces 21
Mercury	Aries 16;8	Aries 4
Moon	Libra 1;4	Libra 0
Ascendent	Gemini 25	c. 10 A.M.

On folio 7, beneath another horoscopic diagram, is the text: Μηνὶ 'Απριλλίῳ α' ἡμέρᾳ ε' ἰνδικτιῶνος δ' ἔτους ,ϛφπθ' εἰσῆλθεν ὁ βασιλεὺς κῦρος 'Αλέξιος εἰς τὸν παλάτιον, καὶ ἀνηγορεύθη. I give below the positions according to the horoscope and according to my computations for *ca.* 10 A.M. of 1 April 1081:

	Horoscope	*Computation*
Saturn	Aquarius 26;40	Aquarius 28
Jupiter	Scorpio 10;50	Scorpio 11
Mars	Leo 19;43	Leo 21
Sun	Aries 18;22	Aries 18
Venus	Aries 27;32	Aries 26
Mercury	Aries 22;34	Aries 24
Moon	Sagittarius 28;53	Sagittarius 18
Ascendent	Gemini 10	c. 10 A.M.

Below this is yet another horoscope with the inscription: τὸ τοιοῦτον θεμάτιόν ἐστι τῆς τοῦ βασιλέως 'Αλεξάνδρου ἐξελεύσεως. I have not been able to date this successfully. The longitudes given in the diagram are as follows:

	Horoscope
Saturn	Virgo 22;16
Jupiter	Leo 12;23
Mars	Capricorn 19;55
Sun	Scorpio 10;30
Venus	Scorpio 9;20
Mercury	Scorpio 13;40
Moon	not given
Ascendent	Scorpio 10;0

[30] The Zîj al-Kabîr al-Ḥâkimî was written by Ibn Yûnis in Cairo *ca.* 990; see E. S. Kennedy, *A Survey of Islamic Astronomical Tables*, Transactions of the American Philosophical Society, N.S., 46, 2 (Philadelphia, 1956), no. 14.

[31] Kûshyâr wrote *ca.* 1010 the Zîj al-Bâligh (Kennedy no. 7) and the Zîj al-Jâmi' (Kennedy no. 9 and pp. 156–157).

[32] Perhaps Ibn Yûnis is being referred to again.

[33] Abû Ma'shar (787–886) was the most important astrologer of his time. It was mainly through him that Islam, and thereby Byzantium, learned something of Indian and Sasanian astrology; see my papers "Historical Horoscopes," *JAOS*, 82 (1962), pp. 487–502 and "Astronomy and Astrology in India and Iran," *Isis*, 54 (1963), pp. 229–246.

[34] Ibn Hibintâ's Kitâb al-Mughnî was written in 941; see C. Brockelmann, *Geschichte der arabischen Literatur*, 1 (Leiden, 1943), p. 252.

Cabasilas,[35] the Hesychast mystic, who wrote a long-winded but intelligent commentary on the third book of the Μεγάλη σύνταξις,[36] and Theodore Meliteniotes,[37] perhaps a relative of Metochites, who explains the astrolabe and Ptolemaic astronomy in the first two books of his Ἀστρονομικὴ τρίβιβλος, written before 1368. As far as has been determined at present this school of astronomers added nothing new to their classical heritage except for Gregoras' realization that the "new" parameter for the length of the tropical year necessitated a reform of the calendar. But their explication of texts was carried on at a fairly high level of comprehension.

The spirit of the late thirteenth and early fourteenth century in Byzantium within a certain group of intellectuals was one of immense pride in the great tradition of which the Empire was the heir and which it was her duty to safeguard from barbarization. Even Metochites, for all his zeal to achieve classicism (most evident in the hexameters of his verses), was criticized by Nicephorus Chumnos for the error of contradicting Plato in his astronomical theories.[38] Since he was raised in such an atmosphere, one might guess that one of Metochites' aims in writing the Στοιχείωσις was to demonstrate the superiority of Ptolemaic astronomy over its rivals. In the introduction to that work he has a hypothetical colleague exclaim,[39] "Be a Greek, and shun the theories of the Indians, the Scythians, or the Persians, or any other foreign ideas!" This command certainly reflects the attitude of many Byzantines in the early decades of the fourteenth century toward those who, like Maximus Planudes, were familiar with foreign astronomical texts. The problem now is to identify these texts.

Professor Neugebauer has shown[40] that a treatise preserved on folios 232ᵛ–285ᵛ of Par. gr. 2425, a manuscript of the fifteenth century, is an exposition of methods of solving astronomical problems derived from an Islamic source, perhaps one of the zîjes of Ḥabash al-Ḥâsib.[41] Besides the common Arabic values for the obliquity of the ecliptic ($23;35^0$) and the maximum latitude of the Moon ($4;46^0$), it utilizes the value of R (150) which appears in Brahmagupta's Khaṇḍakhâdyaka[42] and many early Islamic zîjes influenced by that work. The Byzantine text, as Neugebauer proves, was written between 1072 and 1086.

But Metochites must have been referring to something more extensive than the text in the Paris manuscript, and to something more immediate. George

[35] See Krumbacher, pp. 158–160; Sarton, 3, pp. 1438–1439; and Beck, pp. 780–783.

[36] Edited by I. Camerarius, Κλ. Πτολεμαίου Μεγάλης Συντάξεως Βίβλ. ιγ (Basel, 1538), pt. 2, pp. 131–194.

[37] See H. Usener, *Ad historiam astronomiae symbola* (Bonn, 1876), pp. 8–21 reprinted in *Kl. Schr.*, 3, pp. 330–349; Krumbacher pp. 623 and 625; Mercati pp. 172–191; Sarton, 3, pp. 1512–1514; and Beck, p. 792.

[38] On the conflict between Chumnos and Metochites see, besides Ševčenko's *Études sur la polémique*, his "Le sens et la date du traité 'Anepigraphos' de Nicéphore Chumnos," *Bull. de l'Acad. roy. de Belgique, Classe des Lettres*, 5th Ser., 35 (1949), pp. 473–488, and J. Verpeaux, *Nicéphore Choumnos* (Paris, 1959), pp. 52–62 and 151–170.

[39] Sathas, pp. πη'-πθ'.

[40] In a paper which has not yet been published.

[41] See Kennedy nos. 15, 16, and 39 and pp. 151–154.

[42] Khaṇḍakhâdyaka 3, 8 in the edition of Babua Misra (Calcutta, 1925); 1, 30 in that of P. C. Sengupta (Calcutta, 1941).

Chrysococces[43] tells us what it was. In the introduction to his Ἐξήγησις εἰς τὴν σύνταξιν τῶν Περσῶν, written in or shortly after 1347, he says, in summary: "I studied Persian astronomy with a priest from Trebizond named Manuel. He reported that a certain Chioniades, who had been raised in Constantinople, fell in love with mathematics and other sciences. After he had mastered medicine,[44] he wished to study astronomy; he was informed that, in order to satisfy his desire, he would have to go to Persia. He traveled to Trebizond, where he was given some assistance by the Emperor Comnenus, and thence proceeded to Persia itself, where he persuaded yet another Emperor to aid him. He eventually learned all that he wished to know, and returned to Trebizond, bearing away from Persia a number of astronomical texts which he translated into Greek. The best of these texts had no commentary; the present ἐξήγησις fulfills the need for one."

Sixteen of the letters of Gregory Chioniades have been preserved in a manuscript in Vienna.[45] From these we learn that he did indeed travel to Persia—in fact to Tabrîz, the Mongol capital, where he was Orthodox Bishop[46]—and that he received some assistance from the Emperor of Trebizond, Alexius II Comnenus (1297–1330).

In several Greek manuscripts of the early fourteenth century translations of Arabic or Persian astronomical works are found. Vat. gr. 211 (V), which was written before 1308,[47] contains versions of the Zîj as-Sanjarî of ʿAbd ar-Raḥmân al-Khâzinî (*ca.* 1120), the Greek freedman of a judge in Marv,[48] the Zîj al-ʿAlâʾî of ʿAbd al-Karîm ash-Shirwânî al-Fahhad (*ca.* 1150),[49] a short

[43] See I. Bullialdus, *Astronomia philolaica* (Paris, 1645), *Tabulae philolaicae*, pp. 211–232; H. Usener, *Ad historiam*, pp. 23–37 reprinted in *Kl. Schr.*, 3, pp. 350–371; Lampros in Νέος Ἑλληνομνήμων, 15 (1921), pp. 332–336; U. Lampsides, "George Chrysococcis, le médecin, et son oeuvre," *BZ*, 38 (1938), pp. 312–322; and Sarton, 3, p. 688. No account of Chrysococces is reliable.

[44] In Ambr. 693 (Q 94 sup.), a manuscript of the fifteenth or sixteenth century, on folios 336–347, is a text entitled: Ἀντίδοται ἐκ Περσείας κομισθεῖσαι καὶ ἐξελληνισθεῖσαι παρὰ τοῦ φιλοσοφωτάτου καὶ ἰατρικωτάτου κυροῦ Γεωργίου τοῦ Χιονιάδου. George Choniates (Sarton, 3, p. 438), whose name is the *lectio facilior*, must be fictious; but is George Chioniades the same as Gregory?

[45] Edited by Ἰ. Β. Παπαδοπούλου, "Γρηγορίου Χιονιάδου τοῦ ἀστρονόμου Ἐπιστολαί," Ἐπιστημονικὴ Ἐπετηρὶς τῆς Φιλοσοφικῆς Σχολῆς τοῦ Πανεπιστημίου Θεσσαλονικῆς, 1 (1927), pp. 151–205; cf. the notes by X. Χαριτωνίδης, *ibid.*, pp. 260–280. On Chioniades, see also Μητροπολίτης Τραπεζοῦντος Χρυσάνθος in Ἀρχεῖον Πόντου, 4–5 (1933), pp. 332–340, and Sarton, 3, p. 438. N. A. Οἰκονομίδης in his excellent article, "Σημείωμα περὶ τῶν ἐπιστολῶν Γρηγορίου τοῦ Χιονιάδου," Ἀρχεῖον Πόντου, 20 (1955), pp. 40–44, has demonstrated that Gregory's eighth letter, addressed to Lucites, was written in (or shortly after) September 1301, but his contention that Gregory was then in Trebizond is not convincing. It is, however, known from Joseph Lazaropoulos (A. Papadopoulos-Cerameus, *Fontes historiae imperii Trapezuntii* [Petropol, 1897] pp. 65–66; cited by both Metropolitan Chrysanthus and Oeconomides) that, "Γρηγόριος ἐν ἱερεῦσι καὶ μονοτρόποις σεβασμιώτατος... ὁ Χιονιάδης καλούμενος, προστάξει βασιλικῇ καὶ ἀξιώσει, ἅμα πρεπούσῃ δωροφορίᾳ" was in Trebizond on 24 June 1302, presumably on his way to the Mongol Court.

[46] See my article "Δάρας τὸ νῦν λεγόμενον Ταυρές," *Bull. de l'Acad. Roy. de Belgique, Classe des Lettres*, 5th Ser., 48 (1962), pp. 323–326.

[47] The owner has noted dates four times on blank pages or in margins. The first note is on folio 160ᵛ, where the year is mentioned as 1619 of the Romans, 707 of the Arabs, 677 of the Persians, and 6816 of Creation (between 30 December 1307 and 20 June 1308); on folio 174ᵛ is recorded 14 May of the year 6828 of Creation and 1631 of the Romans (14 May 1320); on folio 180ᵛ, in the margin, 13 March of the year 6830 of Creation or 18 Khardâd of the year 681 (read 691) of the Persians (13 March 1322); and on folio 234 1620 of the Romans, now 1633, 6817 of Creation, now 6830, 708 of the Arabs, now 722, and 678 of the Persians, now 691 (A.D. 1309, now 1322).

[48] Kennedy no. 27 and pp. 158–161.

[49] Kennedy no. 84.

zîj of Shams ad-Dîn al-Bukhârî, and some less important texts; the same translations, in somewhat different order, are found in a fifteenth-century codex, Vat. gr. 1058 (v).[50] Identical texts and, in addition, the long zîj of Shams ad-Dîn are preserved in Laur. 28, 17 (L), which was written in 1323; but the tables which appear in the two Vaticani are not present in the Laurentianus. These tables—those belonging to the Zîj as-Sanjarî as well as those belonging to the Zîj al-ʿAlâʾî—are the source of many of the tables upon which Chrysococces wrote his exegesis; this fact proves that the texts in V, v, and L are translations by Gregory Chioniades.

The Zîj as-Sanjarî has survived complete in at least two Arabic manuscripts (BM Or. 6669 and Vat. ar. 761), and extracts from it are found in two others. The Greek version, while preserving the order of the original (see the appendix in which I compare the two), represents a shortened redaction. The calendaric tables in Chioniades' translation are for Arab, Persian, Roman, and Sultanic (or Malikî) years, with a special table of Syrian months added. The tables of the mean motions of the planets are for hours, days, months, years, and thirty years according to the Arabic calendar, the epoch being 421 Hijra or A.D. 1030 at a geographical longitude of 90^0 E. The tables of equations and of latitudes are straightforward; the methods involved have, for the most part, been discussed by Neugebauer.

The tables of the Zîj al-ʿAlâʾî are far more interesting for several reasons, not the least of which is that the Arabic original is lost. The calendaric material explains Roman, Persian, Arab, Hebrew, and Sultanic years. Epochal longitudes of the planets are given both for the beginning of the Era of Yazdijird (16 June 632) at a geographical longitude of 84^0 E and for the beginning of the year 541 Yazdijird (1 February 1172). Though parameters are given for the mean motions of the planets for one day, a month of the Persians, a year of the Arabs, a year of the Persians, thirty years of the Arabs, thirty years of the Persians, and 36,0,0,0,0,0,0,0 or 100,776,960,000,000 days to six sexagesimal places, they do not seem to have been used in constructing the tables of mean motions. The last table of parameters—that for 36,0,0,0,0,0,0,0 days—belongs to the Zîj as-Sanjarî rather than the Zîj al-ʿAlâʾî, but some of the other parameters are known from other sources to be al-Fahhad's. Further investigation is required to clarify this situation.

The tables of the mean motions of the planets themselves are arranged substantially as are those in the Zîj as-Sanjarî, except that the elements of the Persian calendar are substituted for those of the Arabic. The tables of correction of the Sun include the epoch longitude of the Sun's apogee, the anomaly, and the equation for each degree of corrected anomaly, so that the true longitude of the Sun minus the motion of its apogee from epoch can be read off directly. The tables of corrections for the other planets are arranged in such a way that the equations are always positive; this is achieved by adding 360^0 or some other constant equal to or greater than the maximum equation to all entries.

[50] Analyzed by O. Neugebauer in his *Studies in Byzantine Astronomical Terminology*, Transactions of the American Philosophical Society, N.S., 50, 2 (Philadelphia, 1960).

Both the Zîj as-Sanjarî and the Zîj al-ʿAlâʾî contain numerous tables of trigonometrical functions such as are common in Islamic astronomical works.

The Zîj of Shams ad-Dîn al-Bukhârî preserved in L is not accompanied by tables, but a study of the examples which this text gives proves that it is a commentary on the tables of the Zîj al-ʿAlâʾî. Shams ad-Dîn, according to his incomplete horoscope,[51] was born 11 June 1254 in Bukhârâ; the many suggestions concerning his identity are without exception uninformed conjectures.[52] The examples in his zîj are dated between 12 February 1293 and 18 November 1296, though he also discusses the horoscope of one Fakhr ad-Dîn, who was born in Tabrîz on 25 August 1268 and who presumably consulted the astronomer-astrologer when he was in his late twenties. It appears that Shams ad-Dîn was working in Tabrîz before Ghâzân Khân established an observatory there in 1300,[53] but the references to Naṣîr ad-Dîn aṭ-Ṭûsî and the Zîj-i Îlkhânî[54] indicate that he had some contact with the observatory at Marâgha.[55] Chioniades calls him his teacher.

The dates of the examples given in the translations of the Zîj al-ʿAlâʾî and the Zîj as-Sanjarî indicate that Chioniades was in Tabrîz in 1295 and 1296. Soon afterwards he seems to have returned to Constantinople, where he stayed for a few years; the references to 12 March and 30 April 1302 and his seventh letter, one of several to Constantine Lucites, must belong to this period. But he returned to the capital of the Mongols as Bishop, possibly in connection with the attempt made by Andronicus II to form an alliance with Ghâzân Khân in the summer of 1302.[56] To this second voyage is to be ascribed his correspondance with Alexius II Comnenus of Trebizond. His translations seem to belong to the brief period when he was in Constantinople between about 1298 and 1302.

L does not contain any of the tables given in V and v; but it does have another set which was undoubtedly also a part of Chioniades' corpus of Islamic astronomy. This set is found again, at least in part, in Vat. gr. 191, wherein there are also examples for dates ranging from 14 April 1298 to 1 May 1302; apparently all these examples are worked for the geographical coordinates of Constantinople.[57] In one of them the Zîj al-ʿAlâʾî is quoted. These tables also appear in Vat. gr. 185, fols. 1–21.

The epoch of these tables is 1404 of the Romans or A.D. 1093. The tables of the mean motions of the planets are for hours, days, months, years, and twenty

[51] V, fol. 24, v fol. 323ᵛ, and L, fol. 207.

[52] J. Gildemeister had suggested Shams ad-Dîn as-Samarqandî (Usener, *Ad historiam*, p. 15 and *Kl. Schr.*, 3, pp. 339–340); this identification is repeated provisionally by Sarton in 2, pp. 1020–1021, but he preferred Shams ad-Dîn Mîrak al-Bukhârî in 3, p. 699.

[53] See A. Sayili, *The Observatory in Islam, Publications of the Turkish Historical Society*, 7th Ser., No. 38 (Ankara, 1960), pp. 226–232.

[54] Kennedy no. 6 and pp. 161–162.

[55] See Sayili, pp. 188–223.

[56] Ghâzân Khân received an embassy from Andronicus II at the end of August 1302; see B. Spuler, *Die Mongolen in Iran, Iranische Forschungen*, 1 (Leipzig, 1939), p. 101 (cf. also pp. 107 and 253).

[57] The tables and texts of Vat. gr. 191 have been studied by Neugebauer in an unpublished paper which he was kind enough to let me read. The references, on folio 319ᵛ, to earthquakes on 1 June and 17 July and a lunar eclipse on 18 May 1296 apparently are not to be connected with Chioniades.

years according to the Roman calendar. The equations are tabulated in such a way that the total correction is found immediately. The arguments and anomalies are arranged horizontally and vertically in steps of 12^0 so that the whole table is thirty columns by thirty. The corrections are normed so as to be always positive; the equations themselves appear to be close to those of Ptolemy.

The tables upon which George Chrysococces commented were, as he himself says, translated from the "Persian" by Chioniades. They are constructed for a place which is 72^0 E and 38^0 N; these are the geographical coordinates of Tabrîz according to Chioniades. In fact, as has been remarked, many of Chrysococces' tables are copies or derivatives of those in the Zîj as-Sanjarî and the Zîj al-'Alâ'î.

From the former are taken the table of Famous Cities,[58] and one of the star-catalogues,[59] but the latter has contributed much more, including all of the calendaric material.[60] With minor variations, such as the dropping of one sexagesimal place, Chrysococces' tables of the daily and hourly mean motions of the Moon, its node, and the five star-planets are taken directly from the Zîj al-'Alâ'î; but his parameters for the annual motions are slightly different from al-Fahhad's, a circumstance which involves some inconsistency, but not of a very serious sort. More damaging is the fact that the tables for the determination of the possibility of eclipses are taken from a work which used Arab years though all the rest of his tables are constructed according to the Persian calendar; this lack of coordination, however, is undoubtedly due to the innate advantage of a lunar calendar in compiling such tables. Other tables connected with eclipses, those for parallax, are taken directly from Ptolemy's Handy Tables. Finally, most of the tables for computing planetary latitudes are borrowed with slight modifications from the Zîj al-'Alâ'î.

Chrysococces gives two different sets of tables for the mean yearly motions of the planets. The first shows these motions for 1 to 10, 10 to 100, and 100 to 1000 years. These are the tables which were published by Bullialdus and are usually taken to be Chrysococces'; but there is some evidence to indicate that they are from the Zîj-i Ĩlkhânî of Naṣîr ad-Dîn aṭ-Ṭûsî.[61] The parameters for one year are exactly $\frac{1}{10}$th of those for 10; they in turn are $\frac{1}{10}$th of those for 100; and these $\frac{1}{10}$th of those for 1000. Therefore, though the lower numbers are given with an apparent accuracy of four sexagesimal places (five in the case of the Sun), the only significant parameters are those for 1000 years, which are carried out to only two sexagesimal places (three in the case of the Sun).

The second set of tables of the mean annual motions of the planets in Chrysococces' work gives the mean longitudes at the beginning of every

[58] Vind. phil. gr. 190 (W), fol. 155 = V, fol. 128ᵛ. This was edited by Bullialdus pp. 230–232.

[59] W, fol. 222 = V, fols. 153ᵛ–154. The second catalogue, in Vind. phil. gr. 87, fol. 33, is dated in the year 6854 of Creation or 715 Yazdijird (A.D. 1346).

[60] W, fol. 150 = V, fol. 161ᵛ; W, fols. 150ᵛ–151 = V, fols. 163–163ᵛ; and W, fols. 151ᵛ–152 = V, fols. 154ᵛ–155.

[61] Nasîr ad-Dîn (Kennedy, p. 161) gives tables arranged in the same way. The only parameter recorded by Kennedy, that for the yearly motion of the apogee, is identical with that in Chrysococces' tables.

Persian year from 710 to about 765, that is, from A.D. 1340 to A.D. 1395. The parameters used in constructing these tables, as has been remarked, are close to but not identical with those which appear in the Zîj al-ʿAlâʾî. The entries in the tables of corrections are consistently positive for all the planets, a constant equal to or greater than the maximum equations being added to all numbers in each case; the same procedure had been followed previously by al-Fahhad. Again, the equations themselves are virtually identical with the Ptolemaic values.

In the manuscripts of the Ἐξήγησις four tables which give the motion of the Moon in minutes and hours for various daily motions are superscribed τοῦ Χρυσοκόκκου.[62] These seem to be the only tables in the whole set which were actually constructed by that astronomer. They are remarkably simple; it was necessary only to divide the daily motions by 24 and the resultant hourly motions by 60. There is, then, nothing whatsoever to indicate that Chrysococces was in any way original.

Another Greek text which utilizes Islamic materials is the Παράδοσις εἰς τοὺς Περσικοὺς προχείρους κανόνας, which has been mistakenly ascribed to Isaac Argyrus. It was written shortly after 25 December 1352, the date for which planetary longitudes are computed in one of its examples. Mercati[63] has suggested that it is a first draft of the third book of Theodore Meliteniotes' Ἀστρονομικὴ τρίβιβλος; this, in fact, is what it seems to be. The two are identical even to the point of sharing an obvious error in converting a Persian into a Christian date. In his preface to this book Meliteniotes has derived his information concerning Islamic astronomers from the first chapter of Chioniades' translation of the zîj of Shams ad-Dîn,[64] but the tables of which he explains the use are Chrysococces' version of Chioniades'. There is nothing new here.

I have not discussed some other Palaeologan adaptions of foreign astronomical tables—for instance, the Greek version of the Alfonsine Tables made on Cyprus by John the Astrologer in 1340,[65] Demetrius Chrysoloras' Latin Tables, whose epoch is 1377,[66] Michael Chrysococces' commentary of 1435 on the Hexapterygon of Immanuel ben Jacob Bonfils,[67] originally written in Hebrew in 1365, or Marcus Eugenicus' exegesis of 1444 on the Latin translation of the tables of Jacob ben David ben Yom-tob,[68] who wrote in 1361; Isaac Argyrus' New Tables, whose epoch is 1 September 1367, are adaptations of Ptolemy's. There is also evidence, as is shown in an appendix, for the existence of Tables of Palaeologus, perhaps written in Nicaea in or shortly after 1436. But enough has been investigated to enable us now to be much clearer about

[62] See W, fols. 170ᵛ–172ᵛ and Vind. phil. gr. 87, fols. 7ᵛ–8ᵛ.

[63] Mercati, p. 175.

[64] This was not realized by L. H. Gray, "Zu den byzantinischen Angaben über den altiranischen Kalender," *BZ*, 11 (1902), pp. 468–472.

[65] In Vat. gr. 212, fols. 26–104ᵛ.

[66] See Krumbacher, p. 110; Beck, p. 751; and Vat. gr. 1059, fols. 482–489. For Demetrius Chrysoloras, Michael Chrysococces, and Marcus Eugenicus, see also G. Mercati, *Scritti d'Isidoro il cardinale Ruteno*, Studi e Testi, 46 (Rome, 1926), pp. 40–50.

[67] His commentary, which is preserved in a number of manuscripts, is being studied by Neugebauer.

[68] See Krumbacher, pp. 115–117 and 496–497, and Beck, pp. 755–758.

the situation of astronomy in Byzantium in the early fourteenth century than was hitherto possible. It is especially apparent that the role of Trebizond as an astronomical center has been vastly overrated.[69] It is true that men like Constantine Lucites[70] and Andreas Libadenus[71] showed an interest in this science and communicated with Chioniades and Gregoras about it; but it is not at all certain that there ever was an Academy of Astronomical Studies or an observatory in Trebizond. Certainly Chioniades, to whose activities as a translator nearly all of the Islamic influence on Palaeologan astronomy can now be traced, seems merely to have passed through Trebizond on his journeys between Istanbul and Tabrîz. It is significant that in all the texts associated with him one finds examples worked for Constantinople and Tabrîz; Trebizond is mentioned only in the preface to Chrysococces' Ἐξήγησις.

Appendix I

PARAMETERS FROM CHIONIADES' WORKS

It should be noted that those parameters which are labeled "approximate" have been sqeezed from the tables as they appear in the manuscripts. They cannot be accepted as definitive until they are confirmed by a thorough study of the textual tradition and an exhaustive investigation into the structure of the tables. But the deviations from the correct figures are probably not very great. For the inferior planets the motion of the anomaly is given.

Yearly mean motions according to the Zîj as-Sanjarî (one year equals 354 days) (approximate)

Saturn	11;52
Jupiter	29;26
Mars	3,5;31
Sun	5,48;55,13
Venus	3,8(sic for 18);15
Mercury	19;46
Moon	5,44;27
Apogee	0;0,52,55

Daily mean motion according to the Zîj as-Sanjarî (approximate)

Saturn	0;2
Jupiter	0;5

[69] Especially by I. B. Papadopoulos. His attempt to create a second Ananias of Shirak and to identify Tychicus with Constantine Lucites is particularly open to criticism. Ananias' autobiography and computus were translated by F. C. Conybeare, "Ananias of Shirak (A.D. 600–650 c.)," *BZ*, 6 (1897), pp. 572–584, and all his works, including those on astronomy, are edited by R. A. Abramian, *Anania Shirakatsi* (Erevan 1958). There seems to be no question that he was a contemporary of Stephanus of Alexandria; see also H. Thorossian, *Histoire de la littérature arménienne* (Paris, 1951), pp. 106–107.

[70] Guilland, *Correspondance*, p. 347, and Beck, pp. 793–794.

[71] See especially his predictions for the year 1336, edited by F. Boll, in *Catal. Cod. Astrol. Graec.*, 7 (Brussels, 1908), pp. 152–160; also Krumbacher, p. 422; N. Banescu, "Quelques morceaux inédits d'Andréas Libadénus," Βυζαντίς, 2 (1911–1912), pp. 358–395; and Beck, p. 794.

Mars	0;31,20
Sun	0;59,8,20
Venus	0;37
Mercury	3;6,20
Moon	13;10,30

Maximum equations according to the Zîj as-Sanjarî (approximate)

Saturn	6;31 and 6;13
Jupiter	5;15 and 11;3
Mars	11;25 and 41;9
Sun	2;12,23
Venus	2;23 and 45;59
Mercury	3;2 and 22;2
Moon	5;1

Yearly mean motion according to the Zîj al-'Alâ'î (one year equals 365 days) (approximate)

Saturn	12;13
Jupiter	30;20
Mars	3,11;16
Sun	5,59;44,51
Venus	3,45;2
Mercury	53;57
Moon	2,9;23

Maximum equations according to the Zîj al-'Alâ'î (approximate)

Saturn	6;31 and 6;25
Jupiter	5;15 and 11;19,30
Mars	11;25 and 38;57,30
Sun	1;58,56
Venus	1;59 and 46;37
Mercury	3;2 and 22;31
Moon	

Period relations from the Zîj as-Sanjarî

PLANETS	REVOLUTIONS	CONJUNCTIONS	DAYS	PERSIAN YEARS and DAYS	MEAN DAILY MOTION (not in text)
Saturn	$1+7;20^0$	29	10965	30y 15d	$0;2,0,35,47^0$
	$2+1;58^0$	57	21551	59y 16d	$0;2,0,36,4^0$
Jupiter	$1+4;48^0$	11	4388	12y 8d	$0;4,59,17,20^0$
	$7+0;8^0$	76	30315	83y 20d	$0;4,59,16,25^0$
Mars	$17+11;6^0$	15	11699	32y 19d	$0;31,26,39,12^0$
	$42+3;9^0$	37	28857	79y 22d	$0;31,26,39,35^0$

PANETS	REVOLUTIONS	CONJUNCTIONS	DAYS	PERSIAN YEARS and DAYS	MEAN DAILY MOTION (not in text)
Sun	$1-0;15^0$	0	365	1y 0d	$0;59,8,13,9^0$
	$4+0;2^0$	0	1461	4y 1d	$0;59,8,22,40^0$
	$8+0;4^0$	0	2922	8y 2d	$0;59,8,22,40^0$
	$25-0;1^0$	0	9131	25y 6d	$0;59,8,20,42^0$
Venus	$8-1;54^0$	5	2920	8y 0d	$0;36,59,10,41^0$
	$16-4;47^0$	10	5839	15y 364d	$0;36,59,33,29^0$
	$24-6;49^0$	15	8759	23y 364d	$0;36,59,25,33^0$
Mercury	$13+2;50^0$	41	4751	13y 6d	$3;6,24,10,18^0$
	$46+0;16^0$	145	16802	46y 12d	$3;6,24,22,58^0$
	79	249	28854	79y 19d	$3;6,24,1,47^0$
Moon	$45+2,18;43^0$	45	1240	3y 145d	$13;10,34,59,1^0$
	$271+1,43;28^0$	269	7412	20y 112d	$13;10,35,2,6^0$
	$572+5,3;48^0$	568	15651	42y 321d	$13;10,35,1,53^0$

Tables of mean motions, apparently from the Zîj al-ʿAlâʾî
For a Persian year (365 days)

Saturn	12;13,39,27,44,5,45 (daily motion of 0;2,0,36,4,33,33)
Jupiter	30;20,30,14[a],24,25 (daily motion of 0;4,59,15,39,41)
Mars	3,11;17[b],12,27,22,45 (daily motion of 0;31,26,39,51,21)
Sun	5,59;45,45,43[c],13[d],45[e] (daily motion of 0;59,8,20,35,25)
Venus	3,45;1,49,41,44,56[f],10[g] (daily motion of 0;36,59,28,43,1,38)
Mercury	53;58,14,38,17[h],15[i],0[j] (daily motion of 3;6,24,22,7,59)
Moon	2,9;23,6,42,49,40 (daily motion of 13;10,35,1,55,32)

a 16MS b 14MS c 55MS d 27MS e 5MS f 53MS g 0MS h 33MS
i 55MS j 58MS

For an Arab year (354 days)

Saturn	11;51,32,50,53,56,42 (daily motion of 0;2,0,36,4,33,33)
Jupiter	29;25,38,24,7,54 (daily motion of 0;4,59,15,39,41)
Mars	3,5;31,19,8,57,54 (daily motion of 0;31,26,39,51,21)
Sun	5,48;55[a],13[b],28,57,30 (daily motion of 0;59,8,20,35,25)
Venus	3,18;14,55,25,51,38[c],12[d] (daily motion of 0;36,59,28,43,1,38)
Mercury	19;47,46,35,6,6 (daily motion of 3;6,24,22,7,59)
Moon	5,44;26,41,21,38[e],48[f] (daily motion of 13;10,35,1,55,32)

a 59MS b 43MS c 36MS d 0MS e 37MS f 36MS

For 30 Persian years (mistaken parameters for yearly motion used)

Saturn	6;49,43,52,2,52,30 (30×12;13,39,27,44,5,45)
Jupiter	3,10;15,8,12,12,30 (30×30;20,30,*16*,24,25)
Mars	5,38;36,13,41,22,30[a] (30×3,11;17,12,27,22,45)
Sun	5,52;52,37,53,32,30 (30×5,59;45,45,*15*,27,5)

Venus	4,30;54,50,52,26,30[b] (30 × 3,45;1,49,41,44,*53,0*)
Mercury	2,59;7,19[c],16,57[d],59[e] (30 × 53;58,14,38,*33,55,58*)
Moon	4,41;33,21,25 (30 × 2,9;23,6,42,*50*)

a 32MS b 59MS c 49MS d 17MS e 30MS

For days		For a Persian month (30 days)
Saturn	0;2,0,36,4,33,33	1;0,18,2,16,46,30
Jupiter	0;4,59,15,39,41	2;29,37,49,50,30
Mars	0;31,26,39,51,21	15;43,19,55,40,30
Sun	0;59,8,20,35,25[a]	29;34,10,17,42,30
Venus	0;36,59,28,43,1,38	18;29,44,21,30,48,49
Mercury	3;6,24,22,7,59	1,33;12,11,3,59,30
Moon	13;10,35,1[b],55,32	35;17,30,57,45,54

a 35MS b 30MS

For 30 Arab years (10631 days)

Saturn	56;8,32,3,48,30,3 (10631 × 0;2,0,36,4,33,33)
Jupiter	2,43;44,3,56,13,31 (10631 × 0;4,59,15,39,41)
Mars	2,51;25,27[a],47,21,51 (10631 × 0;31,26,39,51,21)
Sun	38;27,16,15,14,35[b] (10631 × 0;59,8,20,35,25)
Venus	1,14;14,37,11,42[c],23[d],58 (10631 × 0;36,59,28,43,1,38)
Mercury	4,28;3,45,36,30,49 (10631 × 3;6,24,22,7,59)
Moon	38;17,6,9,58,3,0 (should be 38;17,6,10,34,52)

a 26MS b 34MS c 41MS d 47MS

Revolutions in 36,0,0,0,0,0,0,0 days

Saturn	12,3,36,27,21,18 (1 rev. in 2,59,5;5,22,7,40,48 − days)
Jupiter	29,55,33,58,6,0 (1 rev. in 1,12,10;40,3,8,38,24 + days)
Mars	3,8,39,59,8,6,0 (1 rev. in 11,26;55,36,0,43,12 − days)
Sun	5,54,50,3,32,30,0 (1 rev. in 6,5;14,27,10,4,48 + days)
Venus	3,41,56,52,18,9,46 (1 rev. in 9,43;55,15,18,43,12 + days)
Mercury	18,38,26,12,40,54,0 (1 rev. in 1,55;52,4,50,9,36 + days)
Moon	1,19,3,30,11,33,12,0 (1 rev. in 27;19,17,41,17,48 − days)
Apogee	53,45,36,38 (1 rev. in 40,10,42,23 + days)

Yearly mean motions according to the tables in L (one year equals 365 days) (approximate)

Saturn	12;13,20
Jupiter	30;20,30
Mars	3,11;17
Sun	5,59;45,40
Venus	
Mercury	
Moon	2,9;23

Combined maximum equations according to L (approximate)

Saturn	12;47
Jupiter	16;34
Mars	53;58
Sun	2;0,30
Venus	47;56,30
Mercury	26;49
Moon	7;38,30

Yearly mean motions according to Chrysococces (one year equals 365 days) (approximate)

Saturn	12;12,48
Jupiter	30;19,45
Mars	3,11;16,30
Sun	5,59;44,49
Venus	3,45;1,40
Mercury	53;57
Moon	2,9;23,2
Apogee	0;0,50,55

Maximum equations according to Chrysococces (approximate)

Saturn	6;32 and 6;13
Jupiter	5;15 and 11;3
Mars	11;25 and 42;12
Sun	2;0,30
Venus	1;59 and 45;59
Mercury	3;2 and 22;1
Moon	6;20,18,30

Yearly mean motions according to the 1000-year tables of Chrysococces (one year equals 365 days)

Saturn	12;12,48,2
Jupiter	30;19,20,25,48
Mars	3,11;16,19,25,12
Sun	5,59;44,48,38,1,48
Venus	3,45;1,46,39
Mercury	53;58,14,38,24
Moon	2,9;23,4,58,59
Apogee	0;0,51,25,42,36

Mean motion for 1000 years according to the 1000-year tables of Chrysococces

Saturn	5,33;20,30
Jupiter	1,22;20,30
Mars	1,52;3,40
Sun	1,46;50,33,50

Venus	29;37,30
Mercury	5,30;44,0
Moon	2,23;53,3
Apogee	14;17,8,35

Appendix II

A comparison of the contents of the Zīj as-Sanjarī and its Byzantine translation. The numbers refer to folia, the sigla to the following manuscripts: L = Laurentianus 28, 17. LA = Or. 6669 of the British Museum, London. V = Vaticanus graecus 211. VA = Vaticanus arabus 761. v = Vaticanus graecus 1058.

Preface VA 1^v.

Chapter 1. On fundamentals. VA 5^v.

Chapter 2. On the starting-point and the general approach. VA 7, LA 57.

Chapter 3. On the manner of approaching the question of the Sun. VA 10, LA 59^v.

Chapter 4. On the manner of approaching the question of the Moon. VA 12^v, LA 61.

Chapter 5. On the manner of approaching the question of the superior planets. VA 14, LA 62^v.

Chapter 6. On the manner of approaching the question of the inferior planets. VA 15^v, LA 7^v.

Index of treatises and sections. VA 18, LA 1: L 81^v, V 38, v 273^v.

Treatise 1. On calendars. VA 20: (Part 1) L 82, V 38^v, v 274.

- Section 1. On their bases. VA 20, LA 3^v: (Chapter 1) L 82^v, V 39, v 274^v.
  - Chapter 1. On days, months, and years as components of calendars. VA 20^v, LA 3^v.
  - Chapter 2. On the epochs of calendars. VA 21^v, LA 4^v.
  - Chapter 3. On the differences between calendars. VA 22^v, LA 5.
- Section 2. On calendars in use. VA 23, LA 5^v: (Chapters 2–4) L 83^v, V 39^v, v 275.
  - Chapter 1. On months and years in detail. VA 23, LA 5^v.
  - Chapter 2. On the week-days which begin years and months. VA 24.
  - Chapter 3. On the years of a calendar in days and on the elevation of the days into years and months. VA 25.
  - Chapter 4. On transforming dates from one calendar into another by computation. VA 26.
  - Chapter 5. On transforming dates from one calendar into another by the use of tables. VA 26^v, LA 9.
- Section 3. On festivals. VA 27^v, LA 10: (Chapter 5) L 95^v, V 46^v, v 280.
  - Chapter 1. On what pertains to the days of a month. VA 28, LA 10.
  - Chapter 2. On what pertains to the days of a month and a week VA 28^v, LA 11.

Chapter 3. On what pertains to solar and lunar years and to the days of the week. VA 29, LA 11.

Chapter 4. On the years of the Hebrews and their festivals. VA 30, LA 12.

Treatise 2. On fundamentals, on sines, and on shadows. VA 31, LA 13: (Part 2) L 100^{v}, V 50, v 282^{v}.

Section 1. On fundamentals. VA 31^{v}, LA 13.

Chapter 1. On interpolation. VA 31^{v}, LA 13: (Section 1) L 100^{v}, V 50, v 282^{v}.

Chapter 2. On multiplication and division. VA 32^{v}, LA 13^{v}.

Chapter 3. On the value of π. VA 32^{v}, LA 14.

Section 2. On sines, versines, and arcs. VA 33, LA 14: (Section 2) L 102, V 51, v 283.

Chapter 1. On sines. VA 33^{v}, LA 14^{v}.

Chapter 2. On versines. VA 34, LA 15.

Chapter 3. On arcs. VA 34^{v}, LA 15^{v}.

Section 3. On the three shadows. VA 34^{v}, LA 15^{v}: (Section 3) L 103^{v}, V 52^{v}, v 283^{v}.

Chapter 1. On the first shadow. VA 35, LA 16.

Chapter 2. On the second shadow. VA 35^{v}, LA 16.

Chapter 3. On transforming one shadow into the other VA 36, LA 16^{v}.

Treatise 3. On ascendants. VA 36, [LA 16^{v}].

Section 1. On declination, geographical latitude, altitude, and rising-times for sphaera recta. VA 36, LA 16^{v}: (Part 3) L 103^{v}, V 52^{v}, v 283^{v}.

Chapter 1. On declination. VA 36^{v}, LA 16^{v}: (Chapter 1) L 103^{v}, V 52^{v}, v 284.

Chapter 2. On geographical latitude. VA 37, LA 17: (Chapter 2) L 104, V 53, v 284.

Chapter 3. On the maximum altitudes of the Sun and the stars on the meridian. VA 37, LA 17^{v}: (Chapter 3) L 104^{v}, V 53^{v}, v 284^{v}.

Chapter 4. On knowing the declination from the geographical latitude and the maximum altitude. VA 37^{v}, LA 17^{v}.

Chapter 5. On the rising-times of the signs for sphaera recta VA 37^{v}, LA 17^{v}: (Chapter 4) L 105, V 53^{v}, v 284^{v}.

Section 2. On the azimuth of the point of sunrise and the equation of daylight. VA 38, LA 18: (Part 4) L 105^{v}, V 54, v 284^{v}.

Chapter 1. On the azimuth of the point of sunrise. VA 38, LA 18: (Chapter 1) L 106, V 54, v 285.

Chapter 2. On the equation of daylight. VA 38, LA 18: (Chapter 2) L 106^{v}, V 54^{v}, v 285.

Chapter 3. On the versine of the day-(arc) VA 38^{v}, LA 18^{v}.

Chapter 4. On the arcs of day and night and their hours. VA 38^{v}, LA 18^{v}: (Chapter 3) L 107^{v}, V 55, v 285^{v}.

Chapter 5. On oblique ascensions. VA 39^{v}, LA 19: (Chapter 4) L 108, V 55^{v}, v 286.

Section 3. On the situations of the fixed stars. VA 40, LA 19^{v}: (Part 5) L 108, V 55^{v}, v 286.

Chapter 1. On the correction of their longitudes. VA 40, LA 19^{v}: (Chapter 1) L 108^{v}, V 56, v 286.

Chapter 2. On their distances from the equator and their maximum altitudes. VA 40^{v}, LA 20: (Chapter 2) L 109, V 56, v 286^{v}.

Chapter 3. On the transits of the stars. VA 41, LA 20^{v}: (Chapter 3) L 109^{v}, V 57, v 287.

Chapter 4. On simultaneously rising and setting points. VA 41, LA 20^{v}: (Chapter 4) L 110, V 57^{v}, v 287.

Chapter 5. On the times of risings and settings of the stars. VA 41^{v}, LA 21: (Chapter 5) L 110^{v}, V 57^{v}, v 287^{v}.

Section 4. On what has passed. VA 41^{v}, LA 21: (Part 6, Chapter 1) L 111, V 58, v 287^{v}.

Chapter 1. On what has passed of the day. VA 42, LA 21.

Chapter 2. On what has passed of the night. VA 42, LA 21^{v}.

Chapter 3. On seasonal hours. VA 43, LA 22.

Section 5. On the rising-times and equalizations of the houses. VA 43^{v}, LA 22^{v}.

Chapter 1. On the rising-times. VA 43^{v}, LA 22^{v}: (Chapter 2) L 113, V 59^{v}, v 288^{v}.

Chapter 2. On the hours from the rising-times. VA 44, LA 23: (Chapter 3) L 113^{v}, V 60, v 289.

Chapter 3. On the equilization of the houses. VA 44, LA 23: (Chapter 4) L 114, V 60, v 289.

Section 6. On altitude, the qibla, and the times of prayer. VA 45, LA 23^{v}.

Chapter 1. On altitude. VA 45, LA 24: (Chapter 5) L 115, V 61^{v}, v 289^{v}.

Chapter 2. On the declination-circle of the Sun. VA 46, LA 24: (Chapter 6) L 116, V 62, v 290.

Chapter 3. On the qibla. VA 46, LA 24^{v}: (Chapter 7) L 116^{v}, V 62^{v}, v 290^{v}.

Chapter 4. On the times of prayers. VA 47^{v}, LA 25^{v}.

Treatise 4. On the mean motions of the planets. VA 48^{v}, LA 26^{v}: (Part 7) L 118, V 63^{v}, v 291.

Section 1. On corrections of the revolutions. VA 51, LA 28.

Chapter 1. On the correction of the bases of motions. VA 51, LA 28.

Chapter 2. On the advantages and disadvantages of the revolutions. VA 52, LA 28^{v}.

Section 2. On deriving the mean motions of the planets from computation and from tables. VA 52^v, LA 29: (Chapter 1) L 118, V 64, v 291^v.

Chapter 1. On mean motions from computation. VA 52^v, LA 29.

Chapter 2. On mean motions from tables. VA 53^v, LA 30.

Section 3. On corrections of the mean motions. VA 54^v, LA 30^v: (Chapter 2) L 120, V 65^v, v 292^v.

Chapter 1. On their corrections with regard to the remainder of the difference between the two longitudes. VA 54^v, LA 30^v.

Chapter 2. On the corrections of the mean motions with regard to the equation of time. VA 55, LA 31.

Section 4. On the mean motions with regard to special computations. VA 55^v, LA 31^v.

Chapter 1. On the mean motions for a geographical longitude of 90^0 using the Arabic calendar. VA 56, LA 31^v.

Chapter 2. On the correction of the mean motions for special operations. VA 56^v, LA 32^v.

Section 5. Introduction to world-years and Sultanic years from the three well-known calendars. VA 57, LA 32^v: (Chapter 3) L 121, V 66, v 293.

Chapter 1. On the differences between the world-years and the calendars. VA 57^v, LA 33.

Chapter 2. Introduction to the world-years or Sultanic years. VA 58, LA 33^v.

Chapter 3. On establishing the rules for computing true longitudes. VA 58^v, LA 34: (Chapter 4) L 122, V 67, v 293^v.

Treatise 5. On computing true longitudes and latitudes. VA 59, [LA 34^v]: (Part 8) L 123^v, V 68, v 294.

Section 1. On computing true longitudes. VA 59, LA 34^v: (Chapter 1) L 124, V 69, v 294^v.

Chapter 1. On computing the true longitude of the Sun. VA 59, LA 34^v.

Chapter 2. On computing the true longitude of the Moon. VA 59^v, LA 34^v.

Chapter 3. On computing the true longitudes of the lunar nodes. VA 60, LA 35.

Chapter 4. On computing the true longitudes of the five star-planets. VA 60, LA 35.

Chapter 5. On the exactitude of computations of true longitudes. VA 60^v, LA 35^v.

Section 2. On retrograde and direct motion. VA 61, LA 35^v: (Chapter 2) L 127, V 71, v 296.

Chapter 1. (no title). VA 61, LA 35^v.

Chapter 2. Fundamentals of retrograde and direct motion. VA 61, LA 35^v.

Section 3. On the latitudes of the planets. VA 61^{v}, LA 36: (Chapter 3) L 128^{v}, V 72, v 296^{v}.

Chapter 1. On the latitude of the Moon. VA 61^{v}, LA 36.

Chapter 2. On the latitudes of the superior planets. VA 61^{v}, LA 36.

Chapter 3. On the latitudes of the inferior planets. VA 62, LA 36^{v}.

Section 4. On the velocities and diameters of the Sun and Moon. VA 63, LA 37: (Chapter 4) L 132, V 75, v 298^{v}.

Chapter 1. On daily motion. VA 63, LA 37.

Chapter 2. On the diameter of the Sun. VA 63, LA 37^{v}.

Chapter 3. On the diameter of the Moon. VA 63, LA 37^{v}.

Chapter 4. On the diameter of the shadow. VA 63^{v}, LA 37^{v}.

Chapter 5. On daily motions and diameters in the tables. VA 63^{v}, LA 38.

Treatise 6. On parallax. VA 64, LA 38: (Part 9) L 133, V 76, v 299.

Section 1. Fundamentals necessary for parallax. VA 64, LA 38: (Chapter 1) L 133, V 76, v 299.

Chapter 1. On general matters. VA 64, LA 38.

Chapter 2. On the distance of the Moon from the meridian. VA 64^{v}, LA 38^{v}.

Chapter 3. On the latitude of the clime. VA 64^{v}, LA 38^{v}.

Chapter 4. On the altitude of any degree in the zodiacal circle. VA 64^{v}, LA 38^{v}.

Chapter 5. On the altitude of the Moon. VA 65, LA 38^{v}.

Chapter 6. On the distance of the Moon from the earth. VA 65, LA 39.

Chapter 7. On the three angles necessary in eclipses. VA 66, LA 39^{v}.

Section 2. On parallax by computation. VA 66^{v}, LA 40: (Chapter 2) L 135, V 78, v 300.

Chapter 1. On parallax of the Sun and Moon in the circle of altitude. VA 66^{v}, LA 40.

Chapter 2. On longitudinal and latitudinal parallax of the Moon. VA 67, LA 40^{v}.

Chapter 3. On the correction of the place of the Moon. VA 67, LA 40^{v}.

Section 3. On parallax. VA 67^{v}, LA 40^{v}: (Chapter 3) L 137^{v}, V 79^{v}, v 301.

Chapter 1. On longitudinal and latitudinal parallax. VA 67^{v}, LA 41.

Chapter 2. On the correction of the place of the Moon in longitude and latitude. VA 68^{v}, LA 41^{v}.

Section 4. On the priority of what is observed. VA 69, LA 41^{v}.

Chapter 1. On the priority of what is observed. VA 69, LA 42.

Chapter 2. On the diversity of conditions for the priority of what is observed. VA 69^{v}, LA 42^{v}.

Chapter 3. On the rule of priority in every table for every eclipse. VA 70, LA 42^{v}.

Treatise 7. On conjunctions and oppositions. VA 70, LA 42^{v}: (Part 10, Section 1) L 138, V 80^{v}, v 301^{v}.

Section 1. On knowing this from computations of the equations. VA 70^{v}, LA 43.

Chapter 1. On the hours of conjunction and opposition by means of the equations. VA 70^{v}, LA 43.

Chapter 2. On their fractions. VA 71, LA 43^{v}.

Chapter 3. On their risings. VA 71^{v}, LA 43^{v}.

Section 2. On operations regarding conjunctions and oppositions. VA 71^{v}, LA 43^{v}.

Chapter 1. On the mean motions of the Sun and Moon. VA 72, LA 44.

Chapter 2. On the equations of the Sun and Moon. VA 72, LA 44.

Chapter 3. On the hours of the equations. VA 72^{v}, LA 44^{v}.

Chapter 4. On the fraction of conjunction and opposition. VA 73, LA 45.

Chapter 5. On its transformation into nighttime and daytime. VA 73, LA 45.

Treatise 8. On eclipses. VA 73^{v}, LA 45.

Section 1. On lunar eclipses. VA 73^{v}, LA 45: (Section 2) L 140, V 82, v 302^{v}.

Chapter 1. Fundamentals for lunar eclipses. VA 73^{v}, LA 45^{v}.

Chapter 2. On the prerequisites for an eclipse. VA 74, LA 45^{v}: (Chapter 1) L 140, V 82, v 302^{v}.

Chapter 3. On the times of an eclipse. VA 75, LA 46^{v}.

Chapter 4. On its duration. VA 75^{v}.

Chapter 5. On eclipses from the tables. VA 76: (Chapter 2) L 141^{v}, V 84, v 303.

Chapter 6. On the magnitude of a lunar eclipse. VA 77.

Chapter 7. On the projection of a lunar eclipse. VA 77^{v}.

Chapter 8. On the conclusion of an eclipse. VA 79, LA 47.

Section 2. On solar eclipses. VA 79, LA 47^{v}: (Section 3) L 142^{v}, V 84^{v}, v 303^{v}.

Chapter 1. Fundamentals for solar eclipses. VA 79^{v}, LA 47^{v}: (Chapter 1) L 142^{v}, V 84^{v}, v 303^{v}.

Chapter 2. On the correction of hours for the middle of an eclipse. VA 79^{v}, LA 48.

Chapter 3. On determining the fact of an eclipse and its magnitude. VA 81^{v}, LA 49^{v}: (Chapter 2) L 143^{v}, V 85^{v}, v 304.

Chapter 4. On the times of eclipses. VA 82, LA 49^{v}.

Chapter 5. On knowing the eclipse by means of a table. VA 83^{v}, LA 50^{v}.

Chapter 6. On the corona and the duration of an eclipse. VA 84, LA 51.

Chapter 7. On the magnitude of an eclipse. VA 84v, LA 51v.
Chapter 8. On the darkness of an eclipse and its projection. VA 85, LA 52.

Treatise 9. On first visibilities. VA 85v, LA 52v: (Part 11) L 147v, V 89, v 306.
Section 1. On first visibility of the lunar crescent. VA 85v, LA 52v.
Chapter 1. Fundamentals for the first visibility of the lunar crescent. VA 86, LA 53: (Chapter 1) L 148v, V 89v, v 306v.
Chapter 2. On using simple arcs. VA 87, LA 53v: (Chapter 2) L 151v, V 92v, v 308.
Chapter 3. On correcting the simple arcs according to al-Khāzinī. VA 87v.
Chapter 4. On using the arcs according to al-Battānī. VA 88, LA 54.
Chapter 5. On using the arcs according to Thābit ibn Qurra al-Ḥarrānī. VA 89.
Chapter 6. On what al-Khāzinī looks for in first visibilities. VA 89v.
Chapter 7. On the azimuth of the crescent. VA 90v, LA 55: (Chapters 3, 4, and 6) L 152v, 154, 155v; V 93, 94v, 95v; v 308, 309, 310.
Section 2. On heliacal risings and settings. VA 91, LA 55v: (Chapter 5) L 154v, V 95, v 309.
Chapter 1. Fundamentals for the superior planets. VA 91, LA 55v.
Chapter 2. On appearances and disappearances according to the tables. VA 92.

Treatise 10. On the transfers of years. VA 92v: (Part 12) L 156v, V 97, v 310v.
Section 1. On the transfers of world-years. VA 92v: (Chapter 1) L 157, V 97, v 310v.
Chapter 1. On the times of the transfers of years. VA 93.
Chapter 2. On the mean transfer. VA 93v.
Chapter 3. On the excess of a year. VA 94.
Chapter 4. On the ascendant of the transfer. VA 94v.
Section 2. On the location of the rays of the planets. VA 95: (Chapter 2) L 159, V 98v, v 311v.
Chapter 1. Fundamentals for the location of the rays and their motions. VA 95v.
Chapter 2. On the location of the rays. VA 96.
Chapter 3. On the location of the rays through computation of the horizon and the planets' points of rising. VA 96v.
Chapter 4. On the location of the rays through computation of half of the day-arc. VA 97.
Chapter 5. On the location of the rays according to the opinion of Ptolemy. VA 97v.
Section 3. On the motion of the Haylāj. VA 98v: (Chapter 3) L 162v, V 102, v 313v.

Chapter 1. On the motion of the Haylāj VA 98v.
Chapter 2. On the position of the division. VA 99v.
Section 4. On the intihā' and its motion. VA 100: (Chapter 4) L 165v, V 105, v 315v.
Chapter 1. On the intihā' and its motion. VA 100.
Chapter 2. On the motion of the ascendant-degree of the year-transfer. VA 100v.
Chapter 3. On the transfers of months. VA 100v.
Chapter 4. On the motion of the ascendant of the year-transfer. VA 101.

The Separate Treatise. VA 101.
Section 1. On the ascendant from the altitude of the Moon. VA 101.
Chapter 1. On the hours of the arrivals of the planets at the meridian and the degrees of the transits. VA 101v, LA 56.
Chapter 2. On the hours through estimation. VA 102v, LA 56v.
Chapter 3. On the transformation of the observed altitude of the Moon into its true altitude. VA 103.
Chapter 4. On the correction of the hours and on the ascendant. VA 103v.
Section 2. On the correction of geographical longitude. VA 104.
Chapter 1. (no title). VA 104.
Chapter 2. On geographical longitude from the altitude of the Sun. VA 104v.
Section 3. On changing the computation of true longitudes from one place to another. LA 63.
Chapter 1. On changing the position of the planet. LA 63.
Chapter 2. On changing the hours in conjunctions, oppositions, and lunar eclipses. LA 63.
Chapter 3. On changing the ascendants. LA 63v.
Chapter 4. On altitudes and hours. LA 63v.
Chapter 5. On the visibility of the lunar crescent and solar eclipses. LA 63v.
Section 4. On the true daily motions of the planets. LA 64.
Section 5. On the conjunctions of the planets. LA 65v.
Chapter 1. On the times of the conjunctions. LA 65v.
Chapter 2. On the motion from one conjunction to the next. LA 66.
Section 6. On spheres and transits. LA 66v.
Chapter 1. On the bases of the spheres and their measurements. LA 66v.
Chapter 2. On the minutes of ascent and descent, and on the transits of the planets in their conjunctions. LA 67v.

Appendix III

THE TABLES OF PALAEOLOGUS (BRITISH MUSEUM, MS BURNEY 91, FOL. 8)

Χρὴ γινώσκειν διὰ μεθόδου εὑρεῖν τὰ ἔτη ἃ ἐμετεβλήθησαν παρ' ἡμῶν ἀπὸ τοὺς μῆνας τῶν Περσῶν εἰς τοὺς μῆνας τῶν 'Ρωμαίων. ἀρχὴν τήρησον τὰ 'Ελληνικὰ ἔτη πόσα εἰσὶν, καὶ ἐξ αὐτῶν τῶν πεπληρωμένω ἐτῶν ἄφελον ἔτη ͵ϛϡμγ (6943 A.M. began 1 Sept. 1435 A.D.). τὰ λοιπὰ ἕξωμεν τὰ ῥηθέντα ἔτη. καὶ ὡς ἐν ὑποδείγματος (corrected to ὑποδείγματι) ἔστω 'Ελληνικὰ ἔτη πεπληρομένα εἰς τὴν α' τοῦ Μαρτίου ͵ϛϡν (A.D. 1 March 1443). ἐξ αὐτῶν ἄφελον ͵ϛϡμγ. τὰ λοιπὰ ζ ἕξομεν ἔτη πεπληρομένα. τὸ 'Ελληνικὸν ἔτος ἄρχεται ἀπὸ τὴν α' τοῦ Σεπτευρίου, καὶ τὸ ἡμέτερον ἀπὸ τὴν α' τοῦ Μαρτίου. καὶ πρόσχες ἵνα μὴ συνάρξης αὐτά, καὶ ἐπακολουθήσῃ τι ἄτοπον. ἀλλὰ τὸ μὲν Σεπτέβριον πρὸ μηνῶν ϛ, τὸ δὲ τὸν Μάρτιον μετὰ μῆνας ϛ. καὶ ἐκ περιουσίας τοῦτο ἄφελε ἀπὸ τὰ πεπληρομένα ἔτη τὰ Περσικὰ ωε (805 Yazdijird began A.D. 28 Nov. 1435) ἢ καὶ ἀπὸ τὸ 'Ιουδαϊκὸν 'Εξαπτέριγον (the Hexapterygon of Michael Chrysococces) ιθσογ καὶ ἁπλᾶ ἔτη η ($273 \times 19 + 8 = 5195$ years) καὶ τὰ λοιπά εἰσι τὰ ἡμέτερα ἔτη.

Γίνωσκαι πῶς εἰς τὰ ͵ϛϡμγ ἔτη πεπληρομένα Μαρτίου α' ἦν Περσικὰ ἔτη πεπληρομένα ωε Τυρμᾶ ε' (A.D. 1 March 1436). ἐν τούτοις ἦν ὁ "Ηλιος εἰς τὴν μέσην κίνησιν Τοξότη ιϛ λη' νδ'' μετὴν μέθοδον τῶν ἐτῶν τοῦ Παλαιολόγου, μετὰ γοῦν τὴν μέθοδον τῶν κανονίων τοῦ Χρισοκκούκη (George Chrysococces) εἰς Τοξότην ιϛ λη' ιζ''. τὸ ὕψωμα αὐτοῦ μετοῦ Παλαιολόγου β κθ ιθ' κζ'', μετοῦ Χρισοκκούκη β κθ ιθ' κθ''.

῎Ετι τῆς Σελήνης ἡ μέση κίνησις μετοῦ Παλαιολόγου δ κ ιβ' νε'', ἡ ἰδία κίνησις δ ιβ ιζ' κθ'', τὸ κέντρον ι ιθ ν' η''. μετοῦ Χρισοκκούκη ἡ μέση ὁδὸς δ κ ιβ' νϛ'', ἡ ἰδία κίνησις δ ιβ ιζ' κζ'', τὸ κὲντρον ι ιθ μη' κζ''. αἱ ἐποχαὶ αὗται ἐγένοντο εἰς τὸ μῆκος μοιρῶν νζ.

Chrysococces gives the mean motion of the Sun, measured from its apogee, as 2,54;3,11° at the beginning of 765 Yazdijird (A.D. 8 Dec. 1395), and the longitude of the solar apogee on the same date as 1,28;44,27°. The mean Sun and the apogee have respectively yearly motions of 5,59;44,49,20° and 0;0,50,55°. At the beginning of 769 Yazdijird (A.D. 7 Dec. 1399) Chrysococces says that the mean motion of the Moon is 3;15,55°, its anomalistic motion 29;42,1°, and its double elongation 3,34;7,16°; their yearly motions are respectively 2,9;23,2°, 1,28;43,7°, and 4,19;14,44°. For these functions, without the solar apogee, the motions for the 95 days from Farvardîn 1 to Tîr 5 are respectively 1,32;38,50°, 2,38;34,52°, 2,28;6,30°, and 2,11;51,37°. From these data one gets the following values for 5 Tîr 805 Yazdijird (A.D. 1 March 1436).

	CHRYSOCOCCES	TEXT	TEXT—CHRYSOCOCCES
mean Sun	4,16;34,54°	4,16;38,17°	+ 0;3,23°
solar apogee	1,29;18,24°	1,29;19,29°	+ 0;1,5°
mean Moon	2,19;39,59°	2,20;12,56°	+ 0;32,57°
lunar anomaly	2,11;40,43°	2,12;17,27°	+ 0;36,44°
double elongation	5,18;49,17°	5,19;48,27°	+ 0;59,10°

Chrysococces' figures are for the longitude of Tybênê (Tabrîz), which is 72° E; the text's are for a longitude of 57° E—i.e., on a parallel running close to Nicaea. The difference between the two is 15° or one hour. Therefore, to

multiply the entries in the column headed Text—Chrysococces by 24 should result in mean daily motions:

	(TEXT—CHRYSOCOCCES) × 24
mean Sun	$1;21,12^0$
solar apogee	$0;26^0$
mean Moon	$13;10,48^0$
lunar anomaly	$14;41,36^0$
double elongation	$23;40^0$

Clearly, though these numbers, with the exception of that for the solar apogee, are all in the vicinity of what they should be, there was a serious lack of accuracy in the text's computations.

The Palaeologan Tables give results very close to those obtained by using Chrysococces' work. It appears that it is the purpose of the text preserved in Burney 91 to give the epoch values of these Palaeologan Tables; thus, it seems probable that the Palaeologan Tables were written shortly after 1 March 1436 in or near Nicaea, and that the structure of its tables for determining the longitudes of the Sun and the Moon was modelled on Chrysococces' tables.

Additional Note: After this paper had already reached final proof, the author had the opportunity of examining MS 859 of the Hamidiye Collection in the Süleymaniye Library in Istanbul, and found that the Arabic text of a shortened version of the Zîj as-Sanjarî which it contains is the same as that translated into Greek by Chioniades.